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A new species of *Rousettus* (Chiroptera: Pteropodidae) from Lore Lindu, Central Sulawesi

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Abstract. From March 2000 to July 2001, an intensive biological survey was carried out of the bat fauna of Lore Lindu National Park, Central Sulawesi, Indonesia. The study covered all 11 major vegetation types and an altitudinal range of 300 to 2400 m a.s.l. All habitat types were surveyed applying the same standardized mist-net efforts. Among other things, the survey resulted in the collection of four specimens of *Rousettus* (Megachiroptera) in the swamp forest of Kenawu village, Lindu Lake, Lore Lindu National Park, which represent a new species, described in the present paper. The new species is compared with the other species of *Rousettus* in Indonesia, most notably with the common Sulawesian rouset bat (*Rousettus celebensis*); nearly all skull, dentary and dental dimensions of this new species are smaller than in *R. celebensis*. Moreover, breast fur colour and glans penis morphology are different from these characters in the common Sulawesian rouset bat. The breast fur in the new species is of a cream colour, the abdomen is negro to chocolate, and the sides are brown leather. The glans penis of *Rousettus celebensis* is flattened and triangular, whereas it has an irregular shape in the new species.

Key words: Central Sulawesi, Lore Lindu National Park, *Rousettus linduensis*.

The small to medium sized fruit bats of the genus *Rousettus* (Chiroptera: Pteropodidae), with nine species (Corbet and Hill 1992), are widely distributed, from Indonesia to Southeast and Southwest Asia and Africa and Madagascar, and to the Philippines and Papua New Guinea and the Solomon Islands (Koopman 1993). Corbet and Hill (1992) diagnosed five species of *Rousettus* from Indonesia: *Rousettus* (*Rousettus*) *amplexicaudatus* (Geoffroy, 1810) (S. Burma, Sumatra, Kalimantan, Sulawesi, Moluccas, Jawa, Bali, and Lesser Sunda), *R.* (*R.*) *celebensis* Andersen, 1907 (Sulawesi), *R.* (*R.*) *leschenaultii* (Desmarest, 1820) (Pakistan to Jawa), *R.* (*R.*) *spinalatus* Bergmans and Hill, 1980 (Sumatra and Borneo) and *Rousettus* (*Boneia*) *bidens* (Jentink, 1879) (Sulawesi); implying that Indonesia is the hotspot region of the species diversity in this group.

The type of the genus *Rousettus* is *R. aegyptiacus* (Geoffroy, 1810). *Rousettus* is diagnosed by having upper and lower incisors 2-2, cheek teeth 5/6; P^1 subequal in bulk to the upper incisors; M_1 shorter than M_2 and M_3 combined (Bergmans 1994). The second digit is clawed, the wing membranes attach at the sides of the body except in *R. spinalatus*, and it has a short tail (Andersen 1912; Bergmans and Hill 1980). The wing is attached near the basis of the first phalanges of the first or second toe, or well proximal of this on the first or second metatarsal or in between both (Bergmans 1997). Furthermore, the occipital of the skull is not elongated, the cranial rostrum is not shortened and the premaxilla is not more reduced than usual (Andersen 1912). According to Corbet and Hill (1992) the genus *Rousettus* in the Indomalayan region has two sub genera that are *Rousettus* and *Boneia*. *Boneia* as diagnosed by Andersen (1912) is closely allied to *Rousettus* with accords in most of its cranial and dental and practical all external characters (second digit clawed, a short tail, membranes from sides of back and differing in following particulars like palate much broader anteriorly, premaxillae separated in front, upper and lower canines excessively heavy at base, lower canines directed strongly outward, inner pair of

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upper incisors lost). The general size of the *Boneia* is large, with a forearm more than 90 mm.

Bergmans and Rozendaal (1988) noted 21 species of Pteropodidae in Sulawesi, the Sangihe and Sangir Islands, and Selayar. In their checklist of Indonesian mammals, Suyanto et al. (1998) noted five more species from these islands, adding *Acerodon humilis*, *Cynopterus minutus, Cynopterus sphinx, Pteropus speciosus* and *Pteropus pumilus*. There is agreement between these authors that Sulawesi and surrounding islands have three rouset bats: *Rousettus amplexicaudatus*, *R. celebensis* and *Rousettus* (*Boneia*) *bidens*. *Rousettus* (*Boneia*) *bidens* has usually one upper incisor at each side, a low coronoid process, separated premaxillae, and its upper canine grooved anteriorly, characters which would distinguish this species from the other two (Corbet and Hill 1992). However, Bergmans (1997: 32) argued that when compared to all other *Rousettus* species, most of these characters do not hold. Furthermore, Corbet and Hill (1992) noted that *R. celebensis* is distinguishable from *R. amplexicaudatus* by its long and rather dense pelage, furred tibiae, and a reduced or obsolete antitragal lobe.

From March 2000 to July 2001, the Nature Conservancy carried out an intensive biological survey of the bat fauna of Lore Lindu National Park, Central Sulawesi, Indonesia (Fig. 1). The study of Megachiroptera covered 11 major vegetation types in the park, ranging in elevation from 300–2400 m above sea level. One of the results of the survey was the collection of four specimens of a species of *Rousettus* in swamp forest. In July 2000, a single specimen was collected in Kenawu at Lindu Lake, and between February and March 2001 three further specimens were collected at the same location. We found that these four specimens, when compared to *Rousettus amplexicaudatus* and *Rousettus bidens*, showed distinct morphological characteristics. They appeared more similar to *R. celebensis*, but after a thorough comparison we concluded that these four specimens represent a new species of *Rousettus*, which is described in the present paper.

Methodology

All measurements are in mm. Most of the following detailed measurement points refer to Kitchener and Maharadatunkamsi (1991), Kitchener et al. (1995). Skull: greatest skull length (GSL), condylobasal length (CBL), interorbital breadth (IO), zygomatic breadth (ZB), rostrum length (RL), mastoid breadth (MB), braincase height (HB), mesopterygoid fossa width (MSF), palatal length (LOP), bulla length (BL), postorbital width (POW), braincase width (BW), dentary length (DL), ramus processus coronoideus (RAP). Dention: outside upper canine width (C^1-C^1), upper first and second molar breadth (IN-M^1M^1 and IN-M^2M^2), upper third and fourth premolar breadth (IN-$P^3P^3$and IN-P^4P^4) (alveoli, inside), upper canine to second molar length (C-M^2) (cusp), lower canine to third molar length (C-M_3) (cusp), upper first molar length and width (M^1L and M^1W), upper second molar length and width (M^2L and M^2W), upper third

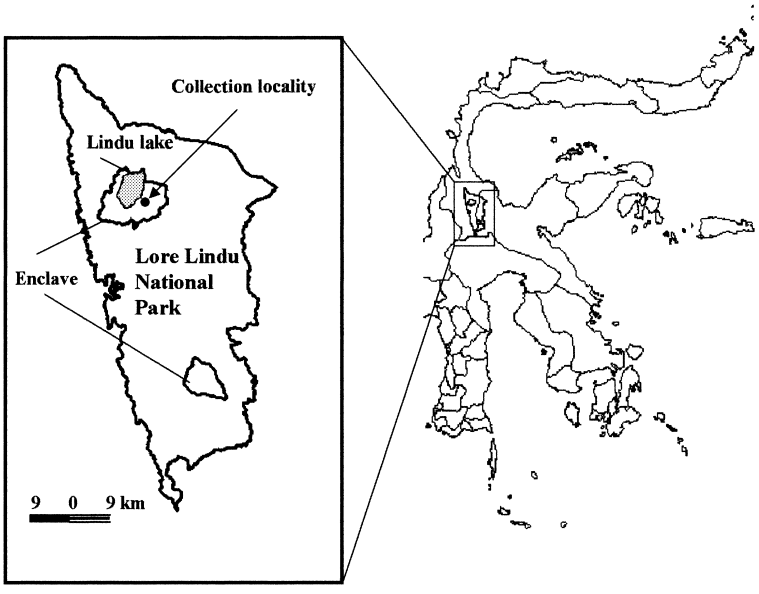

Fig. 1. Collecting locality of holotype and paratypes of *Rousettus linduensis* sp. nov.

premolar length and width (P^3L and P^3W), upper fourth premolar length and width (P^4L and P^4W). External: forearm length (FA), head and body length (HBL), tail length (TAIL), ear length (EAR), tibia length (TIBIA), metacarpal II length (P2), metacarpal II phalanx 1 length (P2-1), metacarpal III length (P3), metacarpal III phalanx 1 length (P3-1), metacarpal IV length (P4), metacarpal IV phalanx 1 length (P4-1), metacarpal V length (P5), metacarpal V phalanx 1 length (P5-1).

Because the specimens from Lore Lindu do obviously not represent *Rousettus amplexicaudatus, R. leschenaultii, R. spinalatus* or *R. bidens*, the differential diagnosis has been restricted. Skull and external measurements were compared, but discriminant function analyses (DFA) were carried out for *R. celebensis* and the new species only. A scanning electron microscope was used after fixation with glutaraldehyde and osmium tetroxide to compare the morphology of the glans penis of *R. celebensis* and the new *Rousettus*. Colour descriptions follow Kornerup and Wanscher (1984).

Results and discussion

Rousettus (Rousettus) linduensis sp. nov

Holotype — Museum Zoologicum Bogoriense (MZB) 23001 (LL field number 146, Fig. 2), adult male, weight

Table 1. Mean, number of sample (N), standard deviation (Std. Dev), minimum and maximum of skull and external measurements (in mm) of *Rousettus celebensis* and *Rousettus linduensis* sp. nov.

Characters	*Rousettus celebensis*					*Rousettus linduensis* sp. nov.				
	Mean	Std. Dev	N	Min	Max	Mean	Std.Dev	N	Min	Max
GSL	39.46	0.52	12	38.73	40.64	39.38	0.39	4	38.81	39.7
BW	15.57	0.37	12	15.11	16.09	15.44	0.2	4	15.31	15.74
CBL	37.57	0.66	12	36.48	38.66	37.46	0.19	4	37.2	37.63
ZB	23.59	0.94	12	22.02	25.12	24.08	0.17	4	23.93	24.25
HB	12.66	0.45	12	11.97	13.42	13.08	0.39	4	12.81	13.65
RL	12.72	0.23	12	12.3	13.04	12.32	0.2	4	12.09	12.55
IO	8.59	0.73	12	7.39	9.57	8.82	0.21	4	8.61	9.02
C^1-C^1	8.23	0.32	12	7.75	8.65	8.22	0.32	4	7.92	8.52
POW	7.69	0.41	12	7.26	8.47	7.07	0.01	4	7.02	7.14
LOP	19.03	0.38	12	18.18	19.57	18.8	0.19	4	18.61	18.97
MSF	5.03	0.19	12	4.61	5.24	5.05	0.23	4	4.78	5.34
BL	3.49	0.17	12	3.02	3.67	3.49	0.01	4	3.39	3.62
MB	14.33	0.35	12	13.91	15.07	14.22	0.26	4	13.9	14.54
RAP	12.26	0.51	12	11.11	13.06	12.11	0.16	4	11.87	12.2
DL	29.76	0.31	12	29.14	30.28	29.76	0.22	4	29.45	29.98
M^1W	1.46	0.01	11	1.35	1.6	1.38	0.2	4	1.09	1.56
M^1L	2.59	0.16	11	2.39	2.84	2.18	0.47	4	1.47	2.49
M^2W	1.1	0.11	11	0.96	1.31	1.16	0.16	4	1.03	1.4
M^2L	1.48	0.01	11	1.27	1.56	1.73	0.55	4	1.29	2.52
P^3W	1.41	0.01	12	1.29	1.55	1.4	0.17	4	1.26	1.65
P^3L	2.43	0.18	12	2.08	2.68	2.45	0.25	4	2.2	2.78
P^4W	1.64	0.01	12	1.52	1.82	1.48	0.33	4	1	1.71
P^4L	2.59	0.17	12	2.12	2.72	2.6	0.01	4	2.51	2.68
IN-M^1M^1	6.66	0.19	12	6.37	6.92	6.84	0.39	4	6.5	7.32
IN-M^2M^2	7.48	0.21	12	7.25	7.97	7.65	0.28	4	7.39	8
IN-P^3P^3	5.58	0.21	12	5.23	5.89	5.65	0.2	4	5.5	5.94
IN-P^4P^4	5.75	0.18	12	5.48	6.05	5.67	0.22	4	5.43	5.96
C-M^2	14.3	0.27	12	14.01	14.78	14.02	0.17	4	13.81	14.18
C-M_3	15.74	0.28	12	15.33	16.25	15.51	0.11	4	15.4	15.62
WEIGHT (gr)	76.36	8.18	12	64	91	90.75	8.06	4	80	99
HBL	100.4	5.69	12	88.5	109.87	112.24	3.32	4	108.32	115.3
EAR	18.43	0.74	12	17.28	19.69	18.55	0.91	4	17.95	19.9
FA	75.81	1.9	12	72.61	79.41	76.73	0.87	4	75.64	77.54
TIBIA	36.87	1.52	12	34.86	39.98	36.8	0.49	4	36.12	37.3
TAIL	25.44	2.02	12	23.38	29.2	28.8	2.29	4	26.11	31.57
P2	35.61	1.33	12	33.31	38.88	35.22	0.57	4	34.39	35.71
P2-1	8.14	0.86	12	6.99	10.25	8.36	1.14	4	7.11	9.58
P3	51.34	0.9	12	50.05	52.6	50.85	0.57	4	50.3	51.64
P3-1	36.28	1.24	12	34.22	38.12	36.34	1.24	4	34.81	37.64
P4	49.88	1.26	12	47.54	52.52	50.05	1.04	4	48.7	50.96
P4-1	26.89	0.9	12	25.1	28.08	26.92	0.48	4	26.31	27.46
P5	49.6	1.32	12	47.99	51.98	49.48	1.52	4	47.65	51.31
P5-1	23.71	1.29	12	20.26	25.71	23.77	0.82	4	22.7	24.54

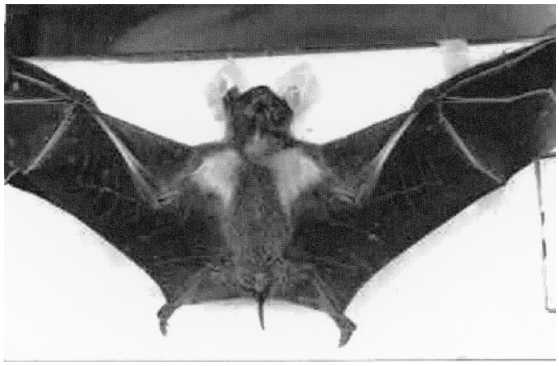

Fig. 2. External view of *Rousettus linduensis* sp. nov. (museum number: MZB23001) collected from vicinity of Lore Lindu National Park, Central Sulawesi, Indonesia.

94 g, skull and dentary separate, carcass fixed in 5 percent formalin and preserved in 70 percent ethanol, collected by M. Yani and Hadianto on 12th July 2000 in the swamp forest at Kenawu village, altitude 930 m above sea level, Lindu lake enclave, Lore Lindu National Park, Central Sulawesi, Indonesia (1°19'8"S, 120°6'8"E) (Fig. 1).

Paratypes — Three specimens collected by M. Yani and M. Annas in swamp forest near the holotype locality, skulls and dentaries separate, carcasses fixed in 5 percent formalin and preserved in 70 percent ethanol: MZB 23002 (field number M 47037), adult male, weight 80 g, collected at 1°22'3.72"S, 120°9'23.58"E, altitude 930 m above sea level, on 14th March 2001; MZB 23003 (field number M 47033), adult male, weight 99 g, collected at 1°21'38.808"S, 120°9'21.01'E, altitude 930 m above sea level, on 15th March 2001; MZB 23004 (field number M 47032), adult male, weight 90 g, at 1°18'57.312"S, 120°6'59.04"E, altitude 930 m above sea level, on 15th March 2001.

Etymology — The new species is named after Lake Lindu, which is the only known collecting area for this species.

Diagnosis — *Rousettus linduensis* is readily diagnosed by the following characters and combinations of these. The tail membrane is dorsally densely furred, the breast fur is cream to white (this may be a male character), the zygomatic width is relatively large, and the braincase is relatively high. (See also discriminant function analysis and univariate plot, Figs. 5 and 6.)

Of the differences between the subgenera *Rousettus* and *Boneia* as summarized by Corbet and Hill (1992), Bergmans (1997) could only confirm the separated premaxillae and the relatively large second lower incisors in *Boneia*. In both characters, *R. linduensis* agrees with typical *Rousettus.* For these reasons, it has been placed in the subgenus *Rousettus*.

Measurements of skull and dentition in *Rousettus linduensis* sp. nov are in Table 1.

Differential diagnosis — Here *Rousettus linduensis* is compared with the five congeneric species from Indonesia, *Rousettus amplexicaudatus*, *R. celebensis*, *R. leschenaultii*, *R. spinalatus* and *R. bidens*.

The length and distribution of the fur and the colour of the pelage distinguish *Rousettus linduensis* from all the other *Rousettus* species. The length of the back fur of *R. linduensis* is 13–15 mm. The pelage colour on the breast in *R. linduensis* males is cream to white. *R. linduensis* has the tail membrane dorsally densely furred. Based on these characters, we could easily distinguish *R. linduensis* from *R. amplexicaudatus, R. leschenaultii* and *R. spinalatus*, which all have an almost naked neck region and an almost bare notopagium (Rookmaaker and Bergmans 1981), a naked tibia and short instead of dense pelage (Corbet and Hill 1992), and no white breast fur in males. The white breast fur in males of *linduensis* distinguishes it from *R. celebensis*. The fur of the forearm in *R. linduensis* is less dense than in *R. celebensis*.

Rousettus bidens as described by Andersen (1912) has one pair of upper incisors. Andersen (1912) wrote that lower incisors in youngish individuals of typical *Rousettus* are distinctly bifid, which character he could not check in *Rousettus bidens* for lack of specimens. Bergmans and Rozendaal (1988) and Bergmans (1994; 1997: 32–33), who could study more specimens than Andersen, found that in *R. bidens* I^1 is present but often deciduous. These authors did not state whether lower incisors in *bidens* are bifid or not. *Rousettus linduensis* has two pairs of upper incisors.

Furthermore, Corbet and Hill (1992) argued that *Rousettus* (*Boneia*) has a forearm length of more than 90 mm (against less than 90 mm in *Rousettus*, a low coronoid process, a basal anterior-posterior diameter of C^1 equal to the length of P^4, and a crown area of I_2 three times that of I_1. From the other differences between the subgenera *Rousettus* and *Boneia* as claimed by Corbet and Hill (1992), Bergmans (1997) could only confirm the separated maxillae and the relatively large second lower incisors in *Boneia.* Bergmans and Rozendaal (1988) measured 5 males of *R. bidens* and found (in mm): FA 97.9 (94.3–103.5), GSL 44.9 (43.9–46.3), CBL 42.5 (41.6–43.9); RL 16.5 (15.3–17.7), mandible length 33.4 (32.6–34.3), mandible height 12.3 (11.6–12.7), IO

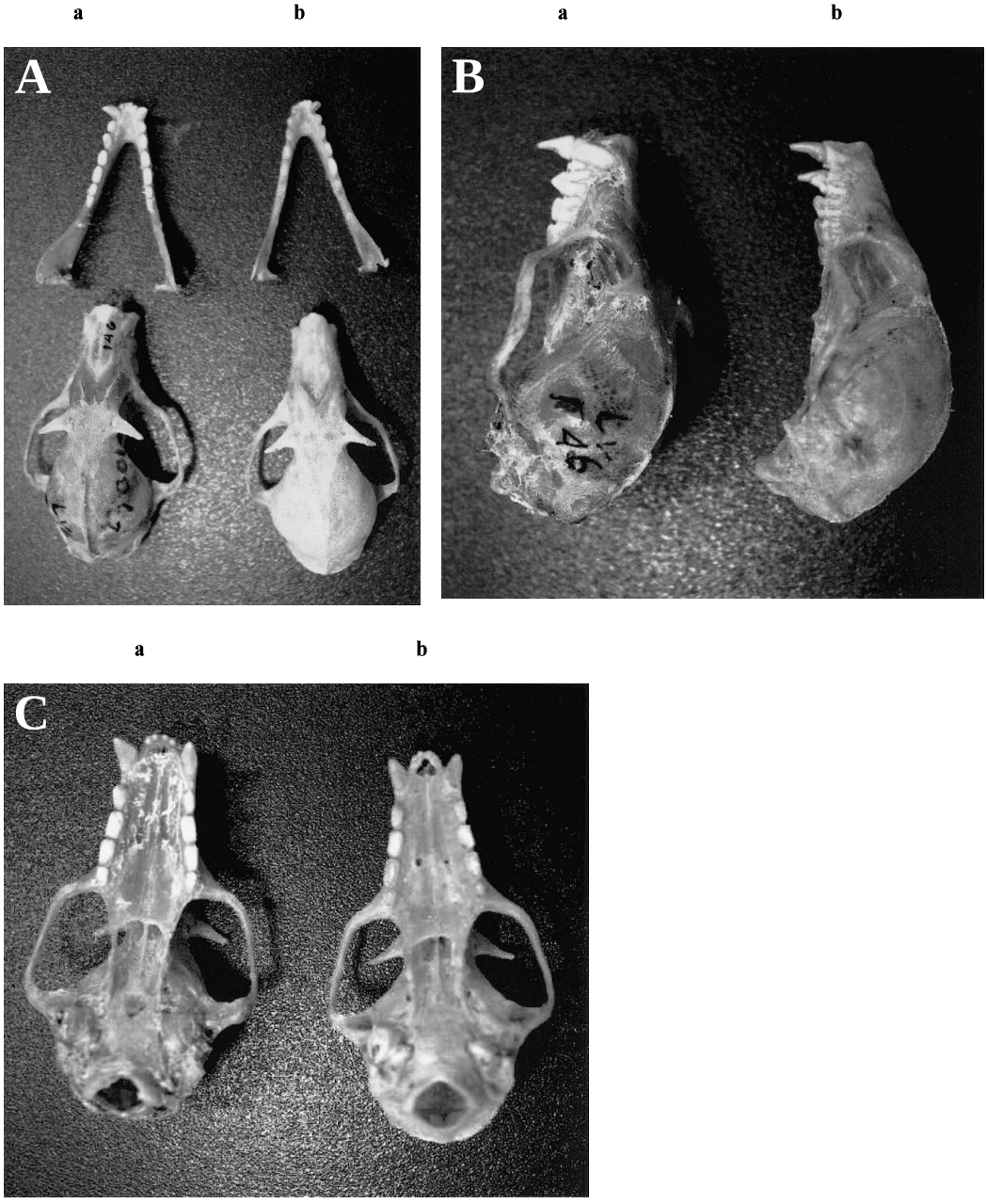

Fig. 3. View of a) *Rousettus celebensis* (MZB23405) and b) *Rousettus linduensis* sp. nov. (MZB23301). Dorsal (A), lateral (B), and ventral (C) view of skull.

8.0 (7.5–8.3), POW 8.4 (8.1–8.7), ZB 27.0 (25.3–27.8). Overall, *Rousettus bidens* is clearly absolutely larger than *R. linduensis*, although in some measurements, such as IO, it is smaller.

Bergmans and Rozendaal (1988) also measured 14 males of *R. amplexicaudatus* from Sulawesi: FA 81.55 (77.3–85.6), P3 51.1 (46.8–54.2), P5 47.6 (43.2–52.6), GSL 36.85 (35.2–38.5), CBL 35.4 (34.2–37.2), ZB 22.3 (20.7–23.3). *R. amplexicaudatus* appears to be larger in body measurements and smaller in skull measurements than *R. linduensis*.

Rousettus linduensis was compared directly to twelve adult male specimens of *Rousettus celebensis* in the Museum Zoologicum Bogoriense (see Apendix I for specimens examined and Table 1 for measurements), which were collected also from Lore Lindu National Park in Central Sulawesi. Nearly all skull, dentary and dental characters of *R. linduensis* are smaller than those in *R. celebensis*. No significant differences were observed in the comparison except for RL ($P < 0.01$, $df =$

1, P = 9.37) and POW ($P < 0.05$, df = 1, P = 8.65). Some skull characters of *R. linduensis* tended to show smaller sizes compared to *R. celebensis* (Fig. 3). For example: GSL, RL. In some other skull and dental characters, *R. linduensis* averages larger than *R. celebensis*: ZB, HB, IO, MSF, M^2W, M^2L, P^3L, P^4L, IN-M^1M^1, IN-M^2M^2, IN-P^3P^3.

In body measurements, significant differences were observed in HBL ($P < 0.01$, df = 1, P = 17.52) and TAIL ($P < 0.05$, df = 1, P = 7.61). The measurements in the four known adult male specimens of *R. linduensis* average larger than those of *R. celebensis* (Table 1): HBL, EAR, FA, TAIL, P2-1, P3-1, P4, P4-1, P5-1, weight. However, some measurements of *R. linduensis* are smaller than in *R. celebensis*: TIBIA, P2, P3, P5.

Rousettus linduensis is similar to *R. celebensis* but the (male) breast fur colour is cream to white, its rostrum is shorter, its zygomatic width is larger, and its braincase is higher.

When compared to the measurements of *Rousettus leschenaultii* from Indonesia (which is larger than populations from the Southeast-Asian mainland) in the paper by Rookmaaker and Bergmans (1981), *R. linduensis* appears absolutely smaller than Indonesian *R. leschenaultii* in body and skull measurements; FA in 19 *R. leschenaultii* males: 84.0–96.3 mm, GSL in 15 males 40.3–43.6 mm, and ZB in 21 males 24.8–27.6 mm.

From *R. spinalatus*, *R. linduensis* differs in the attachment of its wing membranes to the body. In *R. linduensis* the wing membranes are attached, as in other *Rousettus* species, at some distance from the spinal line, while in *R. spinalatus* they are attached at the spinal line. Furthermore, *R. spinalatus* has a larger FA (88.7 mm in an adult male, 80.6–89.3 mm in 3 adult females), and probably a smaller skull (GSL 37.1 mm in an adult male and 35.1–35.9 mm in 2 adult females) than *R. linduensis*. See Bergmans and Hill (1980) and Rookmaaker and Bergmans (1981) for measurements of female *R. spinalatus*; the data on the male are unpublished data provided by Dr. W. Bergmans (in lit., 6 April 2003).

Finally, *R. linduensis* differs from *R. bidens* in being much smaller, in having the premaxillae connected, and in having equally sized, bifid lower incisors. Bergmans and Rozendaal (1988) measured five male *R. bidens* and found (in mm): FA 97.9 (94.3–103.5), GSL 44.9 (43.9–46.3), CBL 42.5 (41.6–43.9); RL 16.5 (15.3–17.7), mandible length 33.4 (32.6–34.3), mandible height 12.3 (11.6–12.7), IO 8.0 (7.5–8.3), POW 8.4 (8.1–8.7), ZB 27.0 (25.3–27.8).

Table 2. Standardized and unstandardized canonical discriminant function coefficients of skull, dental dentary (a) and external character (b).

Character	Standardized Function 1	Unstandardized Function 1
a		
GSL	–1.568	–3.155
POW	1.87	5.144
N-M^1M^1	–0.757	–3.093
RAP	2.205	4.813
Constant		47.594
Variation explain	100%	
b		
HBL	0.906	0.17
EAR	0.52	0.656
TIBIA	–0.72	–0.522
TAIL	0.98	0.473
Constant		–22.728
Variation explain	100%	

Measurements — Measurements of the skull and dentition of *Rousettus linduensis* sp. nov. are presented in Table 1. Measurements of sympatric *R. celebensis* have been added for comparison.

Description of species

Skull — The holotype and paratypes of *R. linduensis* are compared directly with specimens of *R.celebensis* (Table 1, Fig. 3). The skull of *R. linduensis* has a similar length but its rostrum is much wider than that of *R. celebensis*, its rostrum is also shorter (RL 31.28% v. 32.23% of GSL) and its zygomatic breadth is larger (ZB 61.14% v.59.78% of GSL); its mesopterygoid fossa is wider and anteriorly close to the second upper molar. The distance between the mesopterygoid fossa line to the second upper molar in the holotype and paratypes of *R. linduensis* is 3.38–3.50 mm against 3.62–3.81 mm in *R. celebensis*. The braincase is not as flat, the width of braincase across the mastoids is narrower, and the distance between the bullae is wider than in *R. celebensis*. The palate, especially the front, is wider than in *R. celebensis*. In dorsal aspect, the zygoma are more square, in contrast to a narrower and more triangular shape in *R. celebensis*. The mandible slope, from the processus coronoideus to the third lower molar, is steeper than in *R. celebensis*.

One of the paratype specimens of *R. linduensis* (MZB 23004) has no second upper incisors. This is most probably anomalous.

Pelage — The description is based on male specimens preserved in alcohol and later made into dry skins. The fur on the forehead is dark brown to grayish brown. The

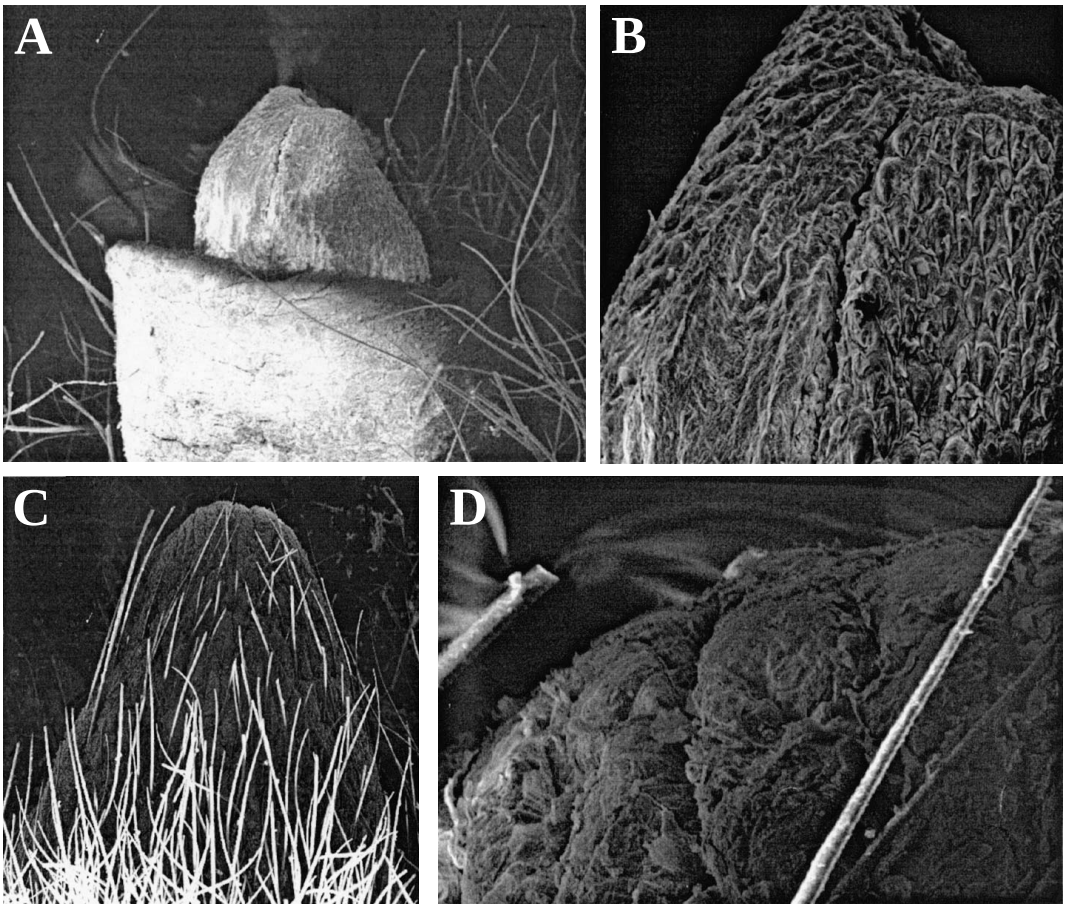

Fig. 4. Morphology of the glans penis of *Rousettus celebensis* (A, B) and *R. linduensis* sp. nov. (C, D), scanning electron microscope images. Picture widths are: 3.77 mm (A), 0.88 mm, (B), 3.77 mm (C), and 0.377 mm (D).

sides of the neck are brownish beige, with a large spot of golden brown on each side. The pelage on the back is longer and more golden brown and reddish than in *R. celebensis*; the tips of the hairs of the back fur are cocoa. The dark brown color of the fur spreads out from the upper arm and joins to form a central line on the lower back. The sides of the rump and the dorsal side of the upper part of the tibia are cinnamon brown. The hairs on the rump have camel colored bases and cinnamon brown tips. The fur on the rest of the tibia is grayish brown. The throat is brownish beige. The breast is cream colored and the abdomen is chocolate brown, with tan on the flanks. The fur on the ventral side of the upper arm and on the adjoining wing membrane is yellowish.

Glans penis — The morphology of the glans penis of *R. linduensis* differs from that of *R. celebensis*. In *R. linduensis* it has an irregular shape, while in *R. celebensis* it is flattened and triangular (Fig. 4). Furthermore, under a scanning electron microscope the top of the glans penis of *R. linduensis* is clearly haired, whereas in *R. celebensis* it is not (Fig. 4).

Biology — Three of the four adult male specimens had a descended scrotum with enlarged testes; the other specimen collect on 15 March 2001 had an inguinal scrotum.

Habitat — All bat specimens were caught using mist nets set 6–8 m from the ground in swamp forest. The following Megachiroptera were also collected from this locality: *R. celebensis*, *Styloctenium wallacei* (Gray, 1866), *Thoopterus nigrescens* (Gray, 1870), *Cynopterus luzoniensis* (Peters, 1861), *Harpyionycteris celebensis* Miller and Hollister, 1921, and *Macroglossus minimus* (E. Geoffroy, 1810).

Multivariate analysis — The DFA was carried out to contribute to distinguishing the morphology of male *R. celebensis* and male *R. linduensis* from Lore Lindu National Park. The cranial, dentary and dental measurements were analyzed separately from the external measurements.

The plots of function 1 and the frequency indicate that the four skulls, dental, dentary characters and the four

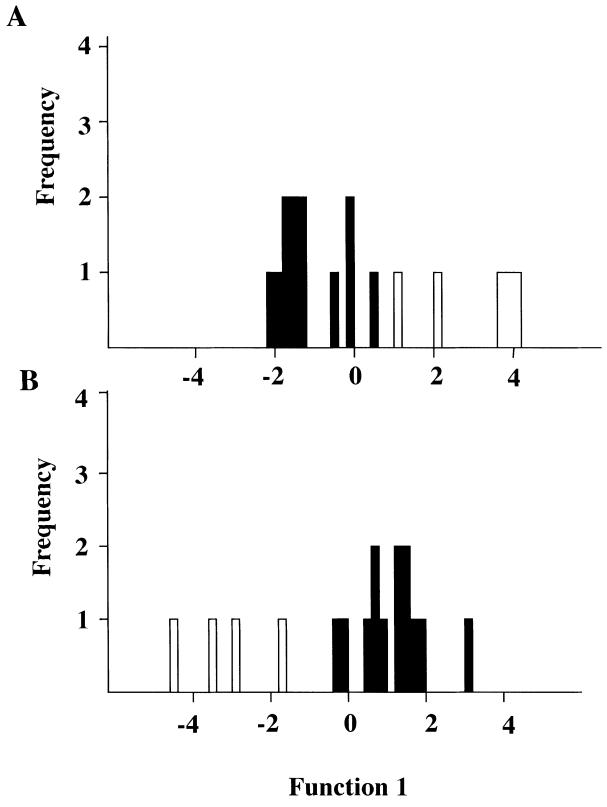

Fig. 5. Plot of a number of function 1 and frequency of skull (A) and external (B) characters of *Rousettus linduensis* sp. nov. (white) and *R. celebensis* (black).

external characters distinguish 100% between the two species (Table 2, Fig. 5). The selected characters in univariate plots for RL versus POW and RL versus first upper molar indicate that *R. linduensis* is smaller than *R. celebensis* (Fig. 6), but the opposite is true for univariate plots of HBL versus FA and HBL versus TAIL, where *R. linduensis* is larger than *R. celebensis*.

Discussion

The find of yet another species of *Rousettus* in Sulawesi, from where already three species were known — already more than from any other island in Indonesia or any region elsewhere for that matter — makes it clear that Sulawesi is a true hot spot for this genus. Within Sulawesi, the northern peninsula is the only region from where *Rousettus bidens* is known and the central region is the only region from where *Rousettus linduensis* is known, which appears to emphasize once more the complex geological history of the island as a composition of parts with different origins. *Cynopterus luzoniensis* is yet another fruit bat species reported here from Sulawesi for the first time.

The ongoing large scale hunting and trapping of fruit bats in the north of Sulawesi and elsewhere seriously

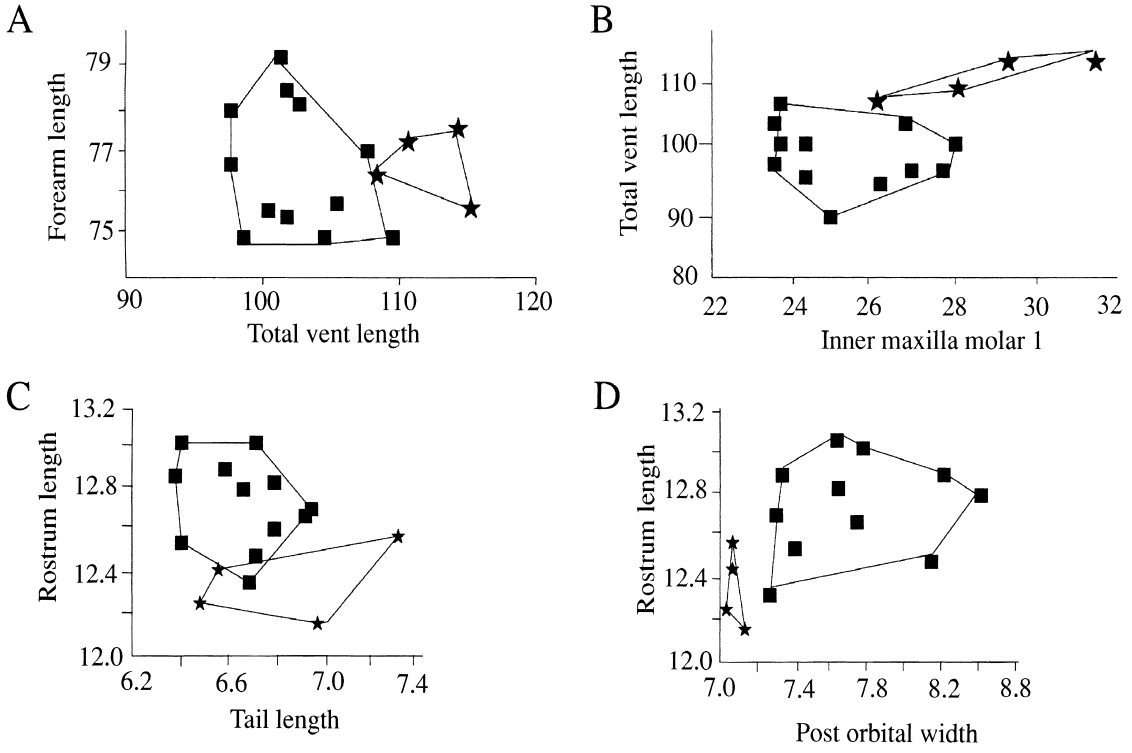

Fig. 6. Univariate plot of some external (A, B) and skull (C, D) characters of *Rousettus linduensis* sp. nov. (stars) and *R. celebensis* (squares).

endangers not only whole species but also the basis for a study of the island's unique fruit bat fauna in its evolutionary perspective. It must be hoped that the growing environmental awareness in Indonesia will help to change the indifferent attitude of the hunters and trappers concerned.

The bat survey in Lore Lindu National Park was carried out between March 2000 to July 2001. All 11 major vegetation types that laid on 300–2100 m above sea level were surveyed. Those are cloud forest, upper montane, montane, lower montane, lower montane moist, marsh, mix garden, monsoon, swamp forest, low land, and degraded lowland forest. Although the all vegetation types already surveyed, *Rousettus linduensis* sp. nov. was only known on swamp forest at 995–1005 m ASL. This species may be expected to be swamp forest, possibly restricted in its distribution by the presence of suitable lower montane moist/swamp forest/marsh those lies closer together. Those three vegetation types have specific Danau Lindu land system type that has land and rock types lacustrine plains. The result of the bat survey indicated that the location is very important for bats roosting and has the highest fruit bat diversity (Maryanto and Yani 2001). It is important that the management authority fix the zonation to protect these animal habitats. In particular, the environs around Lake Lindu contain marsh country that has been identified by these studies as having high mammal species diversity and the site of a newly identified species of bat. Encroachment onto this marsh country and its steady destruction and alienation to paddy is a major concern.

Rousettus linduensis has two pairs of upper incisors and at first it was thought that it would differ in this from *Rousettus (Boneia) bidens*, described by Andersen (1912) as having one pair of upper incisors. It seems in place here to point out that Bergmans and Rozendaal (1988) and Bergmans in his revision of *Rousettus* and some other, African genera thought by many to be related to *Rousettus* (Bergmans 1994; 1997: 32–33), who studied many more specimens of *Rousettus bidens* than Andersen (1912), found that in *R. bidens* I^1 is present but often deciduous. The lower incisors in *linduensis* are about equal in size and bifid. Andersen (1912) wrote that lower incisors in youngish individuals of typical *Rousettus* are unequal in size, the second being larger than the first, and distinctly bifid; the latter character he was unable to check in *R. bidens* for lack of specimens. We now know that the lower incisors in *Rousettus bidens* are not bifid (Dr. W. Bergmans, *in lit*., 6th April 2003).

Regarding the multivariate analysis, the Discriminant Function Analysis or DFA was carried out to contribute to distinguishing the morphology of male *R. celebensis* and male *R. linduensis* from Lore Lindu National Park. Cranial, dentary and dental measurements were analyzed separately from external measurements.

To avoid overfitting the data, a problem inherent in analyzing large sets of characters in DFA, the data sets for skull and external characters were reduced to subsets of four characters. These skull and external characters (skull characters: POW, GSL, first upper molar, and ramus angular process; external characters: head and body, TAIL, EAR, and TIBIA length) were selected to minimize the value of Wilks' lambda. These skull and external characters provided similar clusters for both *R. linduensis* and *R. celebensis* in discriminant function space (as the full set of characters did too). All four skull and external characters were important in the discriminant function and their coefficient values loaded heavily (>0.5) on Function 1. The test functions of the skull, dentary, dental and external characters have significant influence ($P < 0.001$, $df = 4$, and $P < 0.001$, $df = 4$, respectively), with cumulative canonical correlation between the two species of 0.89 and 0.85. Furthermore, the number of functions at group centroids between skull, dental and dentary characters of *R. linduensis* and *R. celebensis* is 1.046 and –3.139 and between external characters –0.840 and 2.941.

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Appendix I.

Specimens of Rousettus celebensis examined for the present stud. — All male specimens examined for comparison with *Rousettus linduensis* were collected from Lore Lindu National Park, Central Sulawesi. MZB 23008 (field number LL 167), Nokilalaki shelter 1, collected by I. Maryanto & M. Yani, 25th July 2000; MZB 23014 (field number LL 216), Kamarora, collected by I. Maryanto & M. Yani, 28th July 2000; MZB 23015 (field number LL 220), Kamarora, collected by I. Maryanto & M. Yani, 30th July 2000; MZB 23016 (field number M47047), Kenawu-Lindu Lake, collected by M. Yani et al., 14th March 2001; MZB 23402 (field number F 52), Kamarora, collected by I. Maryanto & M. Yani, 30th July 2000; MZB 23406 (field number LL 122) Tomado, collected by M. Yani & M. Annas, 30th June 2000; MZB 23409 (field number LL 215), Kamarora, collected by I. Maryanto & M. Yani, 28th July 2000; MZB 23410 (field number LL 196), Nokilalaki shelter 1, collected by I. Maryanto & M. Yani, 27th July 2000; MZB 23412 (field number LL 195), Nokilalaki shelter 1, collected by I. Maryanto & M. Yani, 27th July 2000; MZB 23418 (field number LL 212), Kamarora, collected by I. Maryanto & M. Yani, 28th July 2000; MZB 23423 (field number LL 214), Kamarora, collected by I. Maryanto & M. Yani, 28th July 2000; MZB 23405 (field number F 113), Kadidia, collected by I. Maryanto & M. Annas, 10th October 2000.